Causes and Possible Solutions to the Aquatic Plant Problem in Fort Meadow Reservoir Marlborough and Hudson, Massachusetts

FINAL REPORT

1 MARCH 1982

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BAYSTATE ENVIRONMENTAL

CONSULTANTS, INC.

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CAUSES AND POSSIBLE SOLUTIONS TO THE AQUATIC PLANT PROBLEM IN FORT MEADOW RESERVOIR MARLBOROUGH AND HUDSON, MASSACHUSETTS

CONTRACT NO. DACW33-80-C-0095
DESIGN OF MISCELLANEOUS FACILITIES AND RELATED WORK (1980-1981)
VARIOUS LOCATIONS, NEW ENGLAND DIVISION
WORK ORDER NO. 4

FINAL REPORT

MARCH, 1982

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I. INTRODUCTION

I.a. Lake Setting and Description

Fort Meadow Reservoir is located in Middlesex County, northeast of Worcester, Massachusetts, within the Assabet River drainage basin, at approximately its midpoint. Table I-1 lists the pertinent morphometric data for the reservoir. Fort Meadow Reservoir is not located on the main stem of the Assabet River but rather the upstream reaches of a tributary drainage system known as the Flagg Swamp Brook - Fort Meadow Brook system. The watershed divides are I-495 on the west (upstream), the summits of West Hill (el. 539'), Ockoocanganset Hill (el. approximately 515'), and "Hill 484" to the south, the summits of Wheeler Hill (el. 400'), Round Top Hill (el. 404'), and other unnamed hills to the north and approximately the town beaches of Marlborough (Memorial Beach) and Hudson (Centennial Beach) to the east (downstream). The reservoir is actually a compound impoundment with a very small forebay of a few acres in surface area west of Bolton Road, a larger middle or western basin between Bolton Road and Marlborough Street, and finally a large eastern basin between Marlborough Street and the outlet. The total surface area of the impoundments is 308 acres at a water surface eleveation of 256' (referenced to Mean Sea Level).

Figure I-I shows the Assabet River Water Quality Classification, while Figure I-II shows the projected location of Fort Meadow Reservoir on the long profile of the Assabet River. Proposed Water Quality Classification of the Assabet River system is B (fishable, swimmable), and additionally Fort Meadow Brook has been designated a non-degradable stream, which essentially means it is a water quality limited segment.

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TABLE I-1

MORPHOMETRIC DATA
FORT MEADOW RESERVOIR

Name: Fort Meadow Reservoir

Location: Marlborough and Hudson, Massachusetts

Latitude: 42° 22' 30" N
Longitude: 72° 32' 30" W

<u>Description of Physical Characteristics</u>

Maximum Depth: 10' (West Basin)
23' (East Basin)

Mean Depth: 7' (West Basin)
11' (East Basin)

Surface Area: 308 Acres at el. 256'

Volume (Approximate): 3,200 AF±

Stratification: Below 15'± (East Basin)

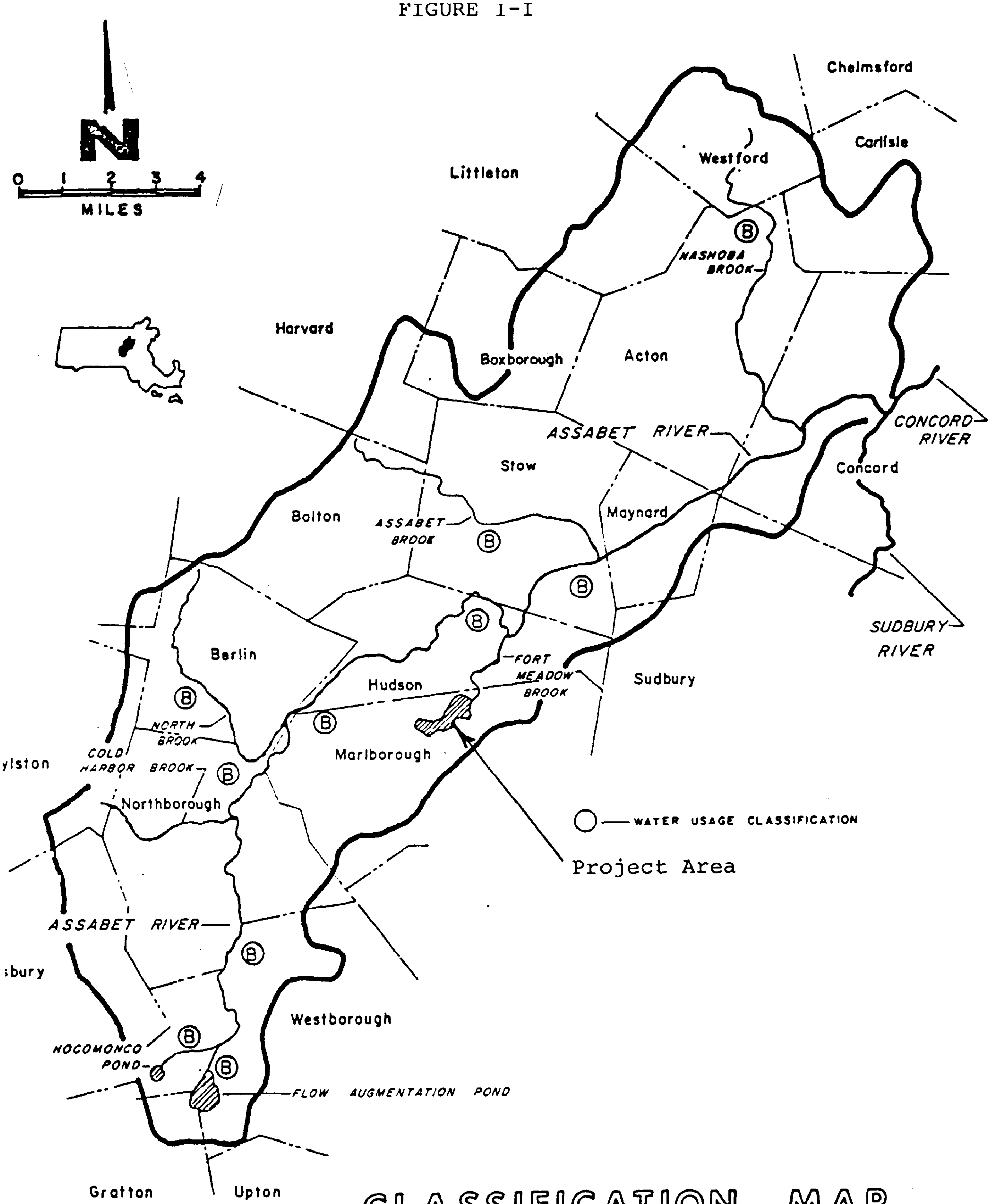
Major Inflows: Flagg Swamp Brook, Sheep Fall Brook, several unnamed smaller streams

Major Outflow: Fort Meadow Brook

Watershed Area: 2,490 Ac. (3.89 MI^2)

Area Affected by Weed Growth (Maximum): 100 Ac.±

FIGURE I-I

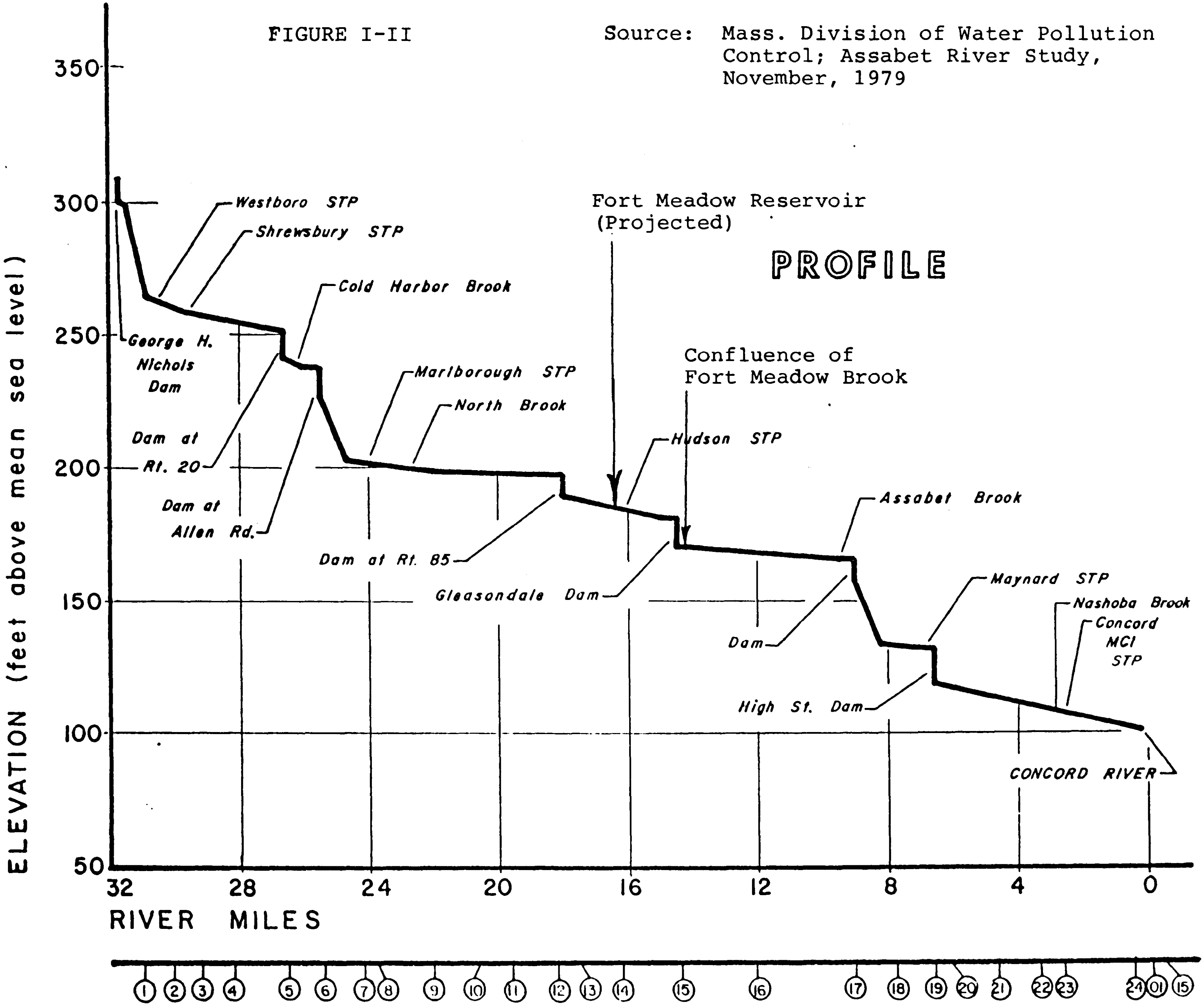


CLASSIFICATION MAP

urce: Mass. Division of Water Pollution Control
Assabet River Study, November, 1979

FIGURE I-II

Source: Mass. Division of Water Pollution Control; Assabet River Study, November, 1979



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I.b. Topographic and Geologic Description of the Watershed

The Fort Meadow watershed is generally elongated in an elliptical fashion with an east-west orientation. Land slopes range from 0-35%, averaging perhaps 8%. The maximum relief within the drainage basin is about 285' from the summit of West Hill (el. 539') to the surface of Fort Meadow Reservoir (el. 256'). Hills shaped by advancing glacial ice known as drumlins dominate the landscape, with normal summit elevations of 450-500' (i.e. Hager Hill, Addition Hill, Ockoocanganset Hill). The principal drainage entering Fort Meadow Reservoir from the west is Flagg Swamp Brook whose source is east of I-495 at about el. 290'. Upon leaving Fort Meadow Reservoir at el. 256', the stream becomes known as Fort Meadow Brook flowing east and north to the Assabet River just west of Boons Pond.

Soils derived from glacial till overlying gneissic to dioritic bedrock typify most of the basin (see Appendix B-4 for Major Soils Descriptions). Glacial cover ranges from 0 to at least 36 feet perhaps averaging 10-15' over most of the basin.

The northern, eastern, and perhaps the bulk of the southern portions of the Fort Meadow Reservoir watershed is underlain by Gospel Hill gneiss of Carboniferous Age, a rock roughly granitic in composition and possibly related to the better known and more widespread Nashoba Formation. The western portion of the watershed near I-495 is probably underlain by the Straw Hill Diorite, dark, intrusive igneous rocks of Late Paleozoic Age. The Fort Meadow Reservoir appears to be located roughly along the axis of a breached anticlinal fold striking about N 30° E, with steeply dipping limbs to the northwest and southeast.

East of Marlborough Street in Hudson, Paxton soils developed on relatively compact and deep glacial till on 8-35% slopes dominate the landscape. The outlet area of Fort Meadow Reservoir and the area along Centennial Beach in Hudson are underlain by sandy, well drained glacial meltwater soils (outwash) of the Hinckley series.

Between Marlborough Street and Bolton Road, deep, well drained outwash soils of sand and gravel, belonging to the Hinckley, Merrimac, and Windsor series, dominate the landscape in a subdued landscape generally below el. 300'. Some poorly drained deep till soils of the Woodbridge and Paxton groups occupy the higher drumloidal hills above the outwash deposits.

The northwestern portion of the watershed shows abundant drumlin till soils of generally shallow depth. Rock outcrops dot the landscape between patches of Hollis and Canton Soils.

The western portion of the drainage basin along Flagg Swamp Book is underlain principally by well drained Hinckley soils which are, in turn, overlain by very poorly drained mucks. Paxton soils, developed over compact glacial till, dominate the area above the Marlborough landfill, and are present to the edge of the Flagg Swamp wetlands. Paxton soils in drumlin tills and ground morraine appear to dominate the southern portion of the drainage basin as well.

Borings taken along Bolton Road from Fort Meadow Reservoir to the landfill area indicate silty, sandy tills generally 10-15' thick are present, with tills depths reaching 36'. The tills appear to be very, very dense below about 15' (see Appendix B-3).

Vegetative Composition

Undeveloped lands, chiefly farmlands comprise approximately 50% of the Fort Meadow Reservoir watershed. The forested areas which generally exist north and west of the West Basin and south of the East Basin include both mixed Upland Deciduous-Evergreen (UD/E) forests and Deciduous Forested Wetlands (DFW).

The vegetative species which characterize the UD/E forests which exist within the watershed of the reservoir include Chestnut Oak (Quercus prinus), Red Oak (Quercus rubra), White Oak (Quercus alba), Shagbark Hickory (Carya ovata), Sassafras (Sassafras albidum), Flowering Dogwood (Cernus florida), White Pine (Pinus strobus), and Mountain Laurel (Kalmia latifolia). In addition, the Deciduous Forested Wetlands are dominated by an assemblage consisting of Red Maple (Acer rubrum), Highbush Blueberry (Vaccinium corymbosum) and Tussock Sedge (Carex stricta). Orchards and pastureland comprise the bulk of the farmland within the watershed.

The northern shoreline of the West Basin is presently maintained as part of a picnic grove. It is 90-95% forested by Upland Deciduous/Evergreen and Deciduous Forested Wetland vegetative assemblages. The southern and western shorelines of the basins have been heavily encroached upon by road construction, land filling for residential and commercial development, and a sanitary landfill.

The shoreline of the East Basin is heavily developed with approximately 90-100% of its northern perimeter and 50% of its southern shore consisting of residential development. Development along the southern perimeter of the basin, however, is solely restricted to the shoreline of the reservoir with a fairly extensive undeveloped Upland Deciduous/Evergreen forested area extending south of Red Spring Road.

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I.c. Historical Lake Uses

Originally, Fort Meadow Reservoir was built in the early 1800's to supply water for the Maynard Textile Mills (now Digital Corp.). Since 1950, its principal usage has been recreational for the Towns of Hudson and Marlborough. The principal use of Fort Meadow Reservoir at present is for water based recreation. Both the Towns of Hudson and Marlborough have established waterfront recreation in the form of swimming and boating at Centennial Beach and Memorial Beach respectively. Both Town beaches are located at the east end of the reservoir in the larger east basin. The water level of Fort Meadow Reservoir is controlled by the Town of Marlborough. The lake can apparently be lowered substantially (7-8 feet?) and this is done every 5-6 years to afford property owners the opportunity to clean their shoreline frontage.

Centennial Beach in Hudson on the northeast shoreline of Fort Meadow Reservoir is a 4.75 acre recreational beach which supports recreational and competitive swimming for about 1,000 persons annually. Boating and fishing also occur at Centennial Beach. Fort Meadow usage by Hudson residents represents 25% of Town sponsored summer recreational activities. A similar program is sponsored by the Town of Marlborough at the 10 acre Memorial Beach adjacent to the outlet area.

A boat house and ramp is maintained by St. Marks School at the southwest end of the east basin near Marlborough Street in Marlborough. These ramps are also used by the general public. A private lake association also maintains a boat ramp in Hudson off of Lake Shore Drive.

The Fort Meadow Reservoir Commission acts as a two-town steering or policing committee to oversee overall policy for the lake regarding such important actions as weed control, the location and control of point source discharges to the reservoir, and assistance in the formulation of control strategies for lake clean-up. Current recreational usage is severely hampered by excessive weed growth which has plagued about 1/3 of the reservoir and by poor footing locally in mucky and stony areas.

I.d. Inventory Point Sources of Pollution

Prior to 1977, leachate contamination from the approximately 40 acre Marlborough landfill was a principal point source discharge to the east basin of Fort Meadow Reservoir. In 1977, the firm of Metcalf and Eddy of Boston designed a leachate interception well system designed to divert landfill leachate to the Marlborough sewage treatment works. In addition, a sedimentation pond was designed as a forebay to Fort Meadow Reservoir to trap landfill cover materials eroded off of graded slopes. The system has been operational for about 3 years. However, water quality analyses of seepage (?) and runoff under Bolton Road from the landfill indicates that leachate diversion may be incomplete and therefore warrants additional monitoring.

A restaurant located near the landfill known as the Keepers II, has been the site of occasionally high bacterial loadings to surface waters. Its proximity to the landfill, however, makes it difficult to isolate effects of possible restaurant discharges (especially older events) relative to landfill leachate pollution. However, the restaurant is now tied in to municipal sewers, hence limiting its effect on Fort Meadow Reservoir water quality.

The only other suspected point source to Fort Meadow Reservoir is a trucking firm located on Pleasant Street, which may be dumping high concentrations of iron to Flagg Swamp Brook. This source has not been documented by water quality testing.

The major sources of pollution to Fort Meadow Reservoir are non-point sources, principally stormwater runoff from an urbanized watershed, and septic system leachate from approximately 25 dwellings on Red Spring Road in Marlborough.

I.e. Land Use

The Fort Meadow Reservoir watershed consists of about 2,500 acres (see Table I-1). The watershed developed land as it is presently zoned is about 80% residential, 10% commercial, 5% industrial, and 5% agricultural. Much of the presently existing residential land was formerly agricultural land and this may have played a significant role on sediment and nutrient build-up in Fort Meadow Reservoir. Approximately 20-25% of the watershed is presently in open space, primarily as lake surface, wetlands, upland forest and agricultural land.

I.f. Limnological Baseline Conditions

a. Morphometric and Sediment Data

Field and office analysis of existing information were utilized to compile the data shown in Table I-1, concerning the morphometric characteristics of Fort Meadow Reservoir. The reservoir occupies roughly a tenth of the watershed area and is located at the eastern end of it. In August and September of 1981, a generalized reconnaissance of the shoreline and benthos region of Fort Meadow Reservoir within the West and East Basins was conducted. Underwater investigations were accomplished utilizing Self-Contained Underwater Breathing Apparatus (S.C.U.B.A.).

Through a brief traverse of the lake bottom at eleven (11) sampling stations, the shoreline and bottom conditions of the basins were characterized in a general manner. The sampling locations are shown in Figure I-III.

It was found that the maximum depth of the West Basin was at 10 feet, with a mean depth of 7.7 feet, and exhibited a fairly constant grade from each station point. Along the peripheral shallow areas, mucks were constantly observed at depths of two (2) feet, underlain by coarser-grained particles.

It was found that the maximum depth of the East Basin was about twenty-five (25) feet, with a mean depth of 10.8 feet, and in shallow areas it exhibited muck depths of zero (0) to two (2) feet, with coarser-grained particles below the muck.

The Fort Meadow mucks exhibited a predominantly silty texture, appearing to be more inorganic than organic in composition. There appears to exist an organic fibrous mat below the silty mucks.

Water visibility was approximately 4½± feet, or about equal to Massachusetts recreational Water Quality Standards. Table I-1 summarizes overall bathymetric and sediment findings. Field descriptions of the materials which were retrieved are found in Appendix B-4.

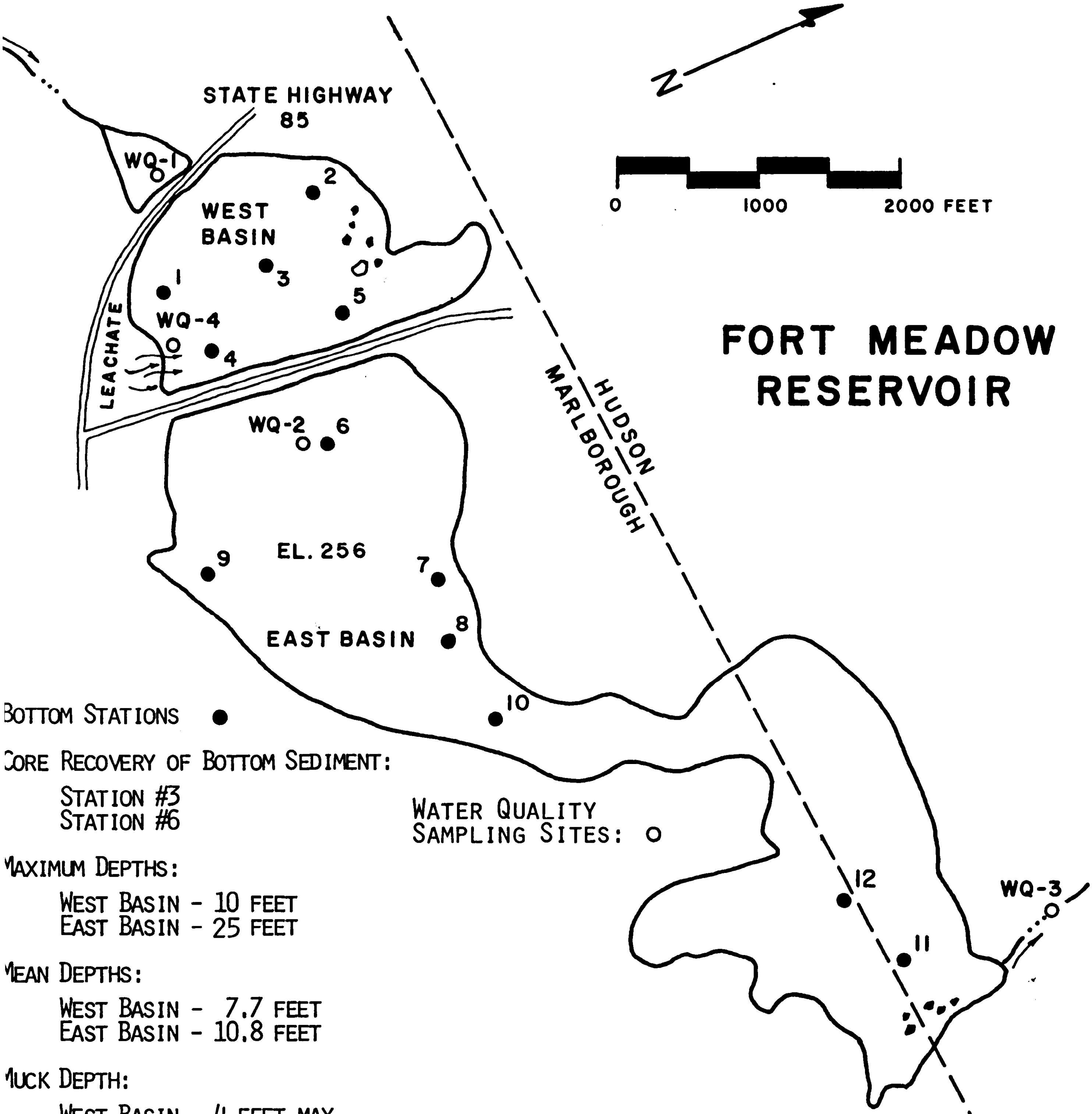
I.f.* Limnological Baseline Conditions

b. Water Quality Data

Based upon limited historical and current observations (see Tables I-2 and I-3) made in September of 1979 by the

*Also contains some items noted under Scope of Work I.g.

FIGURE I-III



BOTTOM STATIONS ●

CORE RECOVERY OF BOTTOM SEDIMENT:

STATION #3
STATION #6

MAXIMUM DEPTHS:

WEST BASIN - 10 FEET
EAST BASIN - 25 FEET

MEAN DEPTHS:

WEST BASIN - 7.7 FEET
EAST BASIN - 10.8 FEET

MUCK DEPTH:

WEST BASIN - 4 FEET MAX.
3 FEET MEAN.
2-4 FEET RANGE.

EAST BASIN - 4+ FEET MAX.
3 FEET MEAN.
2-4 FEET RANGE.

BOULDERS

SEDIMENT & WATER SAMPLING LOCATIONS		
CORP. OF ENGINEERS		
BAYSTATE ENVIRONMENTAL CONSLT		
DATE 10-81	DRAWN BY J S	CHECKED BY C C

TABLE I-2

WATER QUALITY ANALYSIS
FORT MEADOW RESERVOIR
HUDSON AND MARLBOROUGH, MASSACHUSETTS*

	Units	WQ1	WQ2	WQ3**	WQ4
Date Analyzed		8/27/81	8/27/81	8/27/81	8/27/81
Alkalinity	mg/l as $CaCO_3$	23	18	21	69
Hardness Total	mg/l as $CaCO_3$	40	42	36	78
Carbonate Hardness	mg/l as $CaCO_3$	23	18	21	69
Nitrate @N	mg/l	0.0	0.89	3.36	0.0
Surfactants	mg/l	0.0	0.0	0.0	0.0
Ammonia @N	mg/l	0.25	0.35	0.20	4.35
Iron Total	mg/l	0.19	0.03	0.31	2.11
Conductance	Micromhos/CM	220	210	210	340
Suspended Solids	mg/l	3	0	1	39
Volatile	mg/l	3	0	1	10
Fixed	mg/l	0	0	0	29
pH	Std. Units	6.9	6.9	6.7	6.6
Phosphate @P	mg/l	0.03	0.03	0.03	0.09

*All methods utilized in these analyses are EPA approved.
**Flow on 8/25/81 was approximately 2 c.f.s.

TABLE I-3

WATER QUALITY ANALYSIS
FORT MEADOW RESERVOIR
HUDSON AND MARLBOROUGH, MASSACHUSETTS*

	Units	WQ1	WQ2	WQ3	WQ4
Date Analyzed		10/5/81	10/5/81	10/5/81	10/5/81
Alkalinity	mg/l as $CaCO_3$	18	22	20	24
Total Hardness	mg/l as $CaCO_3$	38	36	36	56
Carbonate Hardness	mg/l as $CaCO_3$	18	22	20	24
Nitrate @N	mg/l	0.30	0.00	0.04	0.23
Surfactants	mg/l	0.0	0.0	0.0	0.0
Ammonia @N	mg/l	0.10	0.08	0.12	0.10
Total Iron	mg/l	0.74	0.20	0.23	2.87
Conductance	Micromhos/CM	160	170	180	240
Suspended Solids	mg/l	5	4	10	10
Volatile	mg/l	5	4	8	10
Fixed	mg/l	0	0	2	0
pH	Std. Units	6.9	6.9	7.1	7.2
Phosphate @P	mg/l	0.02	0.02	0.02	0.02

*All methods utilized in these analyses are EPA approved.

TABLE I-4

ELUTRIATE ANALYSIS
EAST BASIN SEDIMENT CORE
FORT MEADOW RESERVOIR

Date Analyzed		10/9/81
Suspended Solids	mg/l	3516
Volatile	mg/l	838
Fixed	mg/l	2678
Ammonia-N	mg/l	1.3
Nitrate-N	mg/l	0.33
Phosphate	mg/l	0.01
Iron	mg/l	2.29
Chloride	mg/l	45.

TABLE I-5

SUMMARY OF BATHYMETRIC AND SEDIMENT FINDINGS
(Refer to Figure I-III for Location)

	Sample Site	Water Depth (Feet)	Approximate Muck Depth (Feet)	Remarks
West Basin	1	7.5'	2.0'	Boulders, Extent unknown.
	2	6.0'	2.5'	
	3	10.0'	3.5'-4.0'	Sediment Core Sample #1
	4	5.0'	2.0'	
	5	10.0'	4.0'	
		Mean Depth		
		7.7'	2'-4'	
East Basin	6	12'	2.0'	Sediment Core Sample #2
	7	10'	2.0'	
	8	4'	0'	No muck. Region not delineated further.
	9	9'	2.0'	
	10	15'	>4'	Depth not determined (Deep pocket)
	11	15'	3.0'	Boulders, extent not determined.
	12	25'	>3.0'	
		Mean Depth		
		10.8'	2'-3'	

Massachusetts Division of Water Pollution Control and by the contractor in August, September and October of 1981, Fort Meadow Reservoir is judged to have slightly acid to alkaline waters, averaging mildly alkaline (pH-7.5) conditions. pH elevation seems to be most evident with late summer conditions, probably due to CO_2 depletion. The reservoir waters are generally of low alkalinity (18-24 mg/l as $CaCO_3$), low hardness (36-42 mg/l as $CaCO_3$) with hardness values about equally split between carbonate hardness (probably bicarbonate) and non-carbonate hardness (probably sulfates and chlorides). Sample locality #4 (see Map, Figure III), a suspected leachate spring from a neighboring landfill operation showed appreciably harder (56, 78 mg/l as $CaCO_3$), more alkaline (69 mg/l as $CaCO_3$), more conductive waters (240, 340 μhos/cm) than remaining portions of the lake. Elevated ammonia levels and suspended solids values at this locality adds further credence to the possibility of contamination of Fort Meadow Reservoir, perhaps by landfill leachate. Finally, available bacterial data taken by Massachusetts DWPC in September, 1979, show significant levels of fecal streptococcus contamination, especially at in-lake stations down-gradient from the landfill. However, long-term bacterial data from the areas of the Hudson and Marlborough Town Beaches (see Appendix C) do not show bacterial problems associated with Fort Meadow Reservoir except for occasional problems near the Keepers II Restaurant.

Dissolved oxygen data are limited for Fort Meadow Reservoir. In September, 1979, Massachusetts DWPC measured 8.4 mg/l D.O. at the inlet with a percent saturation of D.O. equal to 99%. During the same survey, surface D.O. readings in the west and middle basins measured 7.5 and 7.3 mg/l, or roughly 85% of saturation. A D.O. profile in Basin 1 done in October, 1979, showed appreciable D.O. to a depth of 20 feet and high D.O. (85% of saturation) to a depth of 15 feet. A single value of 12 mg/l at a water temperature of 73°F (23°C) was measured by Lycott, Inc. on July 21, 1981, indicating super saturation of D.O. (138%), presumably due to algal blooms and/or macrophytic growth. Since benthic mucks are not extensive, are more inorganic than organic (see Appendix B-4), it can be inferred, that in general, D.O. levels in Fort Meadow Reservoir are reasonably high, with anerobic conditions present in perhaps a few of the deeper holes in the middle and east basins.

Levels of suspended solids are high enough to cause significant turbidity and water transparency problems. The bulk of the suspended solids are volatile, representing algal cell masses and macrophyte fragments. Water transparency as measured by a Secchi Disc reading in the middle basin was 5.5 feet in September of 1979, and about 5 feet in September, 1981.

Elutriate testing of potential dredged material supernatant from the East Basin of Fort Meadow Reservoir shows significant levels of ammonia (NH_3-N) and nitrate nitrogen (NO_3-N) are present in the bottom sediments. The water column above the sediments also shows appreciably NH_3-N, NO_3-N even in the height of the growing season. Levels of nitrate and ammonia near the suspected leachate spring are very high and are probably related to either leachate discharge from the adjacent landfill or the Keepers II Restaurant, as noted earlier. Total phosphorous ranged from 0.02 to 0.09, normally staying close to the 0.02-0.04 mg/l range through the growing season. The limited analyses to date seem to indicate that phosphorous might be the limiting element in Fort Meadow Reservoir. Testing of the potential dredged materials from the East Basin indicates suprisingly low releases of phosphorous and very high values of iron, possibly related to reasonably high D.O. levels in Fort Meadow (see Table I-4).

Current data collected in August and October of 1981 are shown in Tables I-2, I-3 and I-5, while historical data from 1979 (Mass. DWPC) and 1980 (Lycott Environmental Research, Inc.) are included in the Appendix.

I.g In-Lake Sampling

A baseline analysis of the aquatic systems of Fort Meadow Reservoir was compiled utilizing existing information supplemented by biological water quality samples taken in August and September, 1981 and a reconnaissance field review of existing aquatic weed beds. Available existing information included that provided by the Mass. Division of Water Pollution Control which was obtained in early September, 1979, and a letter report dated July, 1980, presented to the Fort Meadow Commission prepared by Lycott Environmental Research, Inc., describing existing weed beds.

The intent of the present investigation was to further characterize the aquatic macrophyte and phytoplankton communities of the reservoir, with fisheries addressed only briefly as existing data was not available for review. Special attention was given to the delineation of and the extent of nuisance weed re-growth in light of herbicide applications applied during July, 1980. The data on macrophyte distribution generated by a BEC September, 1981 survey may be slightly misleading as the peak growth period had expired and plant beds had begun to recede.

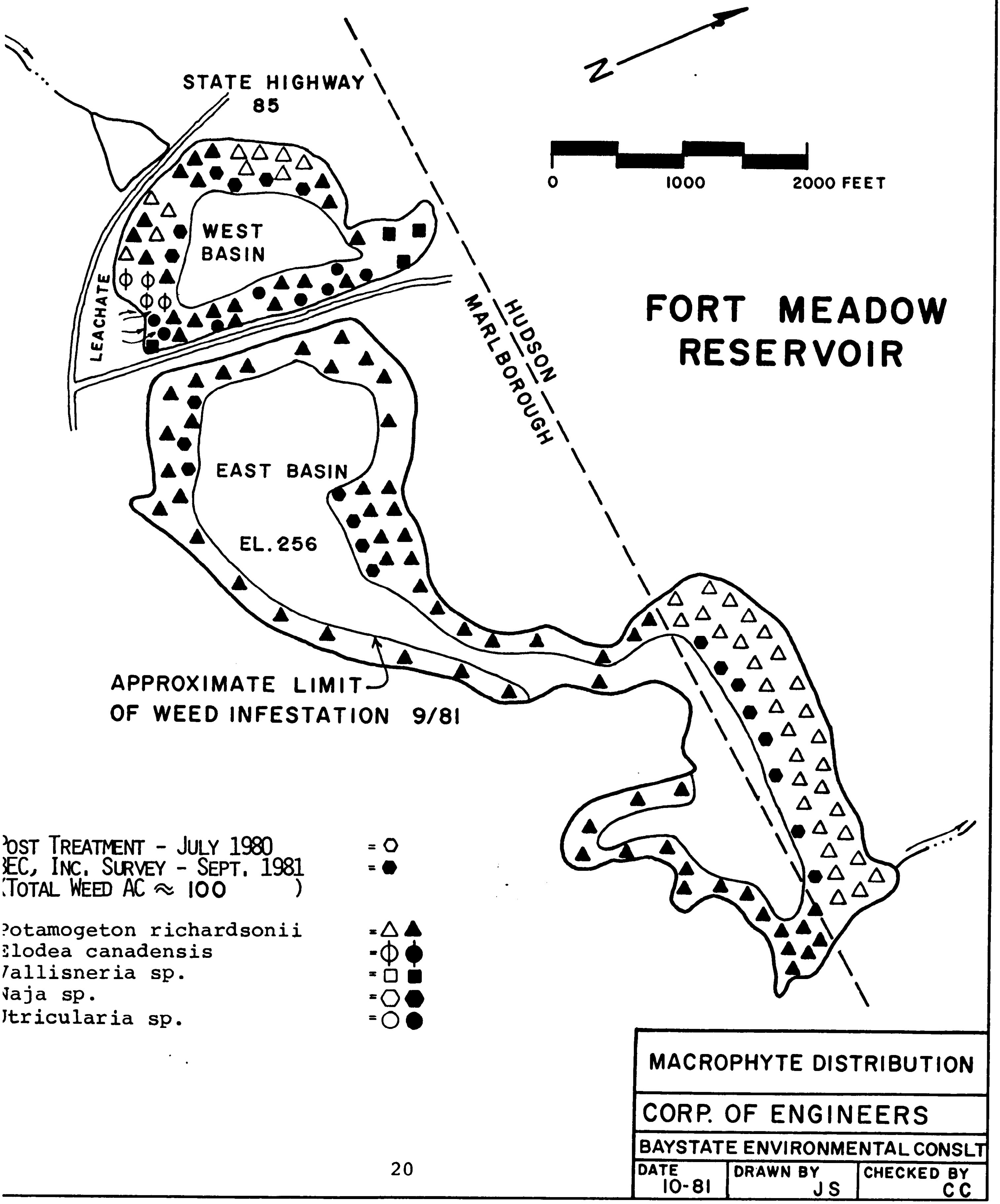
Aquatic Macrophytes

Figure I-IV illustrates the approximate location of the nuisance aquatic macrophyte beds within Fort Meadow Reservoir as of September, 1981. The plan was compiled utilizing the pre and post herbicide application macrophyte delineation map generated by Lycott, Inc., dated July, 1980 as a base plan, and subsequently modified through the current (September, 1981) field observations.

Fort Meadow Reservoir has had a history of aquatic nuisance weed infestation (Lycott, 1980). In June and July of 1980, Lycott Environmental Research, Inc. was retained by the Fort Meadow Commission to control the existing aquatic macrophyte infestation through chemical treatment. The Lycott survey indicated that Potamogeton richardsonii was the major aquatic weed present, generally populating the entire shoreline of both basins of Fort Meadow Reservoir at water depths up to eight (8) feet. The Lycott survey also noted localized nuisance growths of Elodea canadensis and Vallesneria sp. along the southern and northeastern shorelines of the West Basin. Naja sp., a relatively low growing macrophyte commonly accepted as a non-nuisance submergent, was also identified at scattered locations throughout the reservoir.

Subsequent to treatment, Lycott documented that nuisance growths of Potamogeton richardsonii and Elodea canadensis were limited to non-treated areas in the western portion of the West Basin and along the shoreline of the East Basin in Hudson (see Figure 1).

FIGURE I-IV



STATE HIGHWAY 85
WEST BASIN
LEACHATE
EAST BASIN
EL. 256
HUDSON
MARLBOROUGH
FORT MEADOW RESERVOIR
N
0
1000
2000 FEET
APPROXIMATE LIMIT OF WEED INFESTATION 9/81
OST TREATMENT - JULY 1980 =
EC, INC. SURVEY - SEPT. 1981 =
TOTAL WEED AC ≈ 100)
otamogeton richardsonii =
lodea canadensis =
allisneria sp. =
aja sp. =
tricularia sp. =
MACROPHYTE DISTRIBUTION
CORP. OF ENGINEERS
BAYSTATE ENVIRONMENTAL CONSLT
DATE 10-81
DRAWN BY JS
CHECKED BY CC

TABLE I-6

PHYTOPLANKTON CONCENTRATIONS (CELLS/ML)
FOR FORT MEADOW RESERVOIR
MARLBORO/HUDSON, MASSACHUSETTS

Taxonomic Group		Date of Sample	
		9/10/79**	8/25/81
Diatoms			
*Cocconeis sp.		28.6	57.6
*Diatoma sp.			57.6
*Synedra sp.			57.6
	Sub-total	28.6	172.8
Blue-green			
*Coelosphaerium sp.		400.4	
*Anabaena sp.		57.2	28.6
Agmenellum sp.			114.4
	Sub-total	457.6	143.0
Green			
*Sphaerocystis sp.		114.4	
*Closterium sp.		228.8	57.2
*Ankistrodesmus sp.			114.4
Uroglena sp.			57.2
*Chlorella sp.			286.0
Unidentified Colonial		28.6	
	Sub-total	371.8	514.8
Flagellates			
Dinobryon sp.			57.2
Euglenophyte		28.6	
Unidentified Flagellate			
	Sub-total	600.6	57.2
	TOTAL	1,458.6	887.8

*Characteristic of Eutrophic Waters - Phytoplankton Water Quality Relationships in U.S. Lakes, Part VIII - E.P.A. Feb., 1981

**Massachusetts Division of Water Pollution Control Data Taken September 10, 1979.

The current findings indicate that Potamogeton richardsonii has begun to re-colonize the treated areas, with some areas showing heavy reinfestation (see Figure I-4). In addition, the present survey also indicates that a genera change may have occurred in the West Basin as dense growths of Utricularia sp. were found interspersed among the Potamogeton richardsonii, as opposed to Elodea canadensis reported by the Lycott survey in 1980.

It should be stated that the extent of macrophyte regrowth would be more accurately undertaken in late Spring or early Summer 1982, as the BEC survey conclusions are probably conservative due to the time of sampling and initiation of aquatic macrophyte die-back.

Phytoplankton and Chlorophyll a

Phytoplankton samples were taken from an open water station in the East Basin in late August, 1981, in order to supplement the sparse available data.

The two sampling periods indicate that phytoplankton counts are generally low (September, 1979, 1458.6 cells/ml and August, 1981, 887.8 cells/ml) (see Table I-6).

Cell counts in this range are usually indicative of meso-eutrophic conditions, however, this may be an invalid indicator of the trophic condition of Fort Meadow Reservoir as the fairly extensive macrophyte beds may be responsible for the suppression of extensive algal growths. The observation of significant algal blooms in the reservoir following treatment of the macrophytes in 1980 provides some support for this conclusion. In addition, the major portion of the phytoplankton identified for both sample periods have been identified as being associated with eutrophic waters (see Table I-6). The blue-green algae Coelosphaerium sp., a eutrophic indicator and an unidentified flagillate dominate the D.W.P.C. 1979 sample, while the green algal Ankistrodesmus sp. and Chlorella sp. also species indicative of eutrophication, dominate the BEC 1981 sample. Measured available chlorophyll a concentrations of 17.05 mg/l also reflect eutrophic conditions when consideration is given to the presence of dense beds of aquatic macrophytes.

It can be inferred from existing data that qualitively, existing Fort Meadow Reservoir phytoplankton populations are indicative of eutrophic conditions. Some questions remain in regard to quantitative analysis. Additional samples taken during Spring and Fall overturn and mid-Summer would provide the basis for more definitive conclusions.

BEC

Fisheries

Fisheries data was not available, however, the generally shallow bathymetry of the lake and extensive macrophyte community would be conducive to the development of a warm water fisheries. Species expected to occur include largemouth bass (micropterus salmoides), chain pickeral (Esex niger), pumpkinseeds (Lepomis gibbasus), yellow perch (Perca flavescens), brown bullhead (Ictaburus nebulosus), and golden shiner (Notemigonus crysoleucas). Brown bullhead was the only species actually sighted during the September, 1981 field survey.

Conclusions

Fort Meadow Reservoir historically appears to suffer from nuisance aquatic weed infestations (Lycott, 1980). The macrophyte identified as generating the nuisance growths is Potamogeton richardsonii, with minor local infestations of Elodea canadensis and Vallesneria sp.

The populations were suppressed during the summer of 1980 due to the implementation of a herbicide application program. The program appeared to be initially very successful with most of the shoreline being eradicated of the troublesome growths.

Supplemental spot checks, however, undertaken in September, 1981 have revealed substantial re-growth and re-colonization of the weed beds.

Phytoplankton data, though sparse, seems to indicate that phytoplankton populations quantatively are generally low and perhaps suppressed by the extensive macrophyton growths as opposed to the existence of oligo or mesotrophic water quality conditions. The qualitative analysis of these samples clearly indicates that the population is dominated by phytoplankton species indicative of eutrophic conditions.

In order to fully assimilate and justify some of the conclusions present in the aquatic systems evaluation, it would be prudent to augment the minimal existing data with additional water quality samples. These samples should be taken during the Spring and Fall overturns and mid-Summer. Also, the weed beds should be delineated and evaluated during the peak growth season, late Spring/early Summer, in order to assess re-growth patterns after herbicide application, the effectiveness of herbicide application as a restoration alternative and to delineate the beds so that other restoration techniques can be assessed (i.e. weed harvesting).

II. FEASIBILITY STUDY

1. Preliminary Identification and Discussion of Lake Restoration Alternatives

a. Nature of the Problem

The Fort Meadow Reservoir area is characterized by moderate to steep slopes (8-35%) formed by streams draining westerly and southerly, dissecting primarily glacial till deposits over shallow bedrock, and secondarily glacial outwash in the northwestern portion of the basin. The majority of the 2,000± acres above the lake have been intensely developed for residential, commercial, and other uses. Past agricultural and present urban land use practices within the watershed have resulted in the transport of excessive sediments and nutrients to Fort Meadow Reservoir. These events have set the stage for the present eutrophication problem. Urbanization has created artifically steep slopes in road cuts, and on residential and commercial properties, which in turn have exposed relatively easily erodible sub-soils.

When left in a natural, vegetated condition, moderate and steep slopes are relatively stable; however, they are quite easily disturbed by the activities of Man. Disturbance of the slope vegetation by various forms of trespassing (i.e. pedestrian traffic or recreational vehicles) and/or the release of stormwater at the top of the slope, is usually enough to create a severe erosion problem if left unchecked. To these effects must be added those of street sanding and normal sediment and pollutant build-up on urban surfaces as a result of intense activity by Man. Finally, past agricultural practices in the watershed above Fort Meadow Reservoir have contributed substantially to the present sediment and nutrient storehouse.

In addition to the erosion and sedimentation problems plaguing the Fort Meadow system, a relatively high loading of nutrients and bacteria have entered Fort Meadow Reservoir due to the septic system and possibly landfill leachage runoff.

The degradation of Fort Meadow Reservoir appears to be most influenced by the rate of sedimentation within the lake. In areas where sediments have built up to the point where water depth is reduced to a few feet, macrophytic growth has prolifereated and succession has occurred to an emergent wetland. The inflow zone of cove like areas of the shoreline of Fort Meadow Reservoir are examples of such succession. Perhaps up to one-third of the water surface area of Fort Meadow

Reservoir has, or is, rapidly succeeding to emergent wetlands. This succession is progressing rapidly into the lake following the build up of sediments deposited by Flagg Swamp Brook, unnamed tributaries, and stormwater outfalls.

b. Preliminary Restoration Alternatives

There are two basic aspects to the siltation and eutrophication problems of the Fort Meadow System; the causes and the effects. The causes of these problems are primarily associated with land use practices in the watershed. The effects of the siltation and eutrophication problems are primarily manifested in the lake itself. In-lake characteristics such as shallowness, an organic muck bottom, nuisance rooted aquatic plant growths and algal blooms, low transparency, and the disappearance of sport fisheries represent some of the principal effects of the eutrophication process on Fort Meadow Reservoir.

In order to be effective over the long-term, the Fort Meadow Reservoir Restoration Program must deal with the causes of the problem. The alternatives available essentially involve the management of those land use practices within the watershed which contribute the major loadings of sediments, nutrients and other pollutants to the lake, and in-lake restoration methods such as dredging and/or weed harvesting. For the Fort Meadow System, the land management alternatives include: erosion and sediment control measures (particularly during construction projects and at stormwater outfalls), stormwater treatment and/or diversion, and the elimination of specific point source discharges, such as the existing landfill and elimination of on-site, subsurface sewage disposal system failures.

In-lake restoration alternatives include dredging, drawdown, weed harvesting, artificial aeration, nutrient inactivation, dilution/flushing, and bottom sealing. Of these, only dredging and harvesting appear to warrant additional detailed discussion. This is because nutrient levels in the water column are low, thus the probable sources of nitrogen and phosphorous are from the organic substrate. A more limited discussion of less feasible alternates which deal principally with high nutrient levels in the water column is also included. A summary of potential water based (in-lake restoration) and land based (watershed management) techniques is shown in Table II-1.

TABLE II-1

SUMMARY OF POTENTIAL LAKE RESTORATION APPROACHES
FORT MEADOW RESERVOIR

In-lake Techniques	Structural	Non-structural
Dredging	X	
Weed Harvesting	X	
Herbicide Addition	X	
Power Boat Restrictions		X
Level Control	X	
Induced Aeration	X	
Land-based Techniques		
Zoning		X
Land-use Planning		X
Extension of Sanitary Systems		X
Septic Tank Maintenance	X	X
Stormwater Management Programs	X	X
Increased Street Sweeping		X
Increased Catch Basin Maintenance		X
Higher Levels of Leachate Diversion and/or Treatment	X	

2. Specific Restoration Schemes

a. Watershed Management (Land-based Schemes)

1. Stormwater Management Programs

The control of stormwater in the lake basin probably represents the major problem with regard to nutrient flux to Fort Meadow Reservoir. An overall strategy is required to attenuate the impact of stormwater flows originating throughout the basin. Given the relatively small size of the watershed this could be accomplished by the development of control options to address stormwater management concerns on a localized scale. Specifically, application of site tailored stormwater detention facilities may provide the Towns of Marlborough and Hudson with the necessary control program.

The objective of this approach is to mitigate the impact of stormwater runoff principally from developed urban areas on Fort Meadow Reservoir to the extent feasible. For new projects, proper design, construction and maintenance of stormwater facilities would reduce the rate and total amount of runoff from the area being developed to that which would normally have occurred under pre-project conditions. Additionally, stormwater detention facilities would protect the public health and welfare (in terms of water based recreation) and minimize adverse environmental impacts in the Fort Meadow Reservoir.

In designing the stormwater management program, it would be advisable to look at alternative schemes which could:

1. Provide adequate stormwater retention periods to minimize the percentage of incoming solids which would be carried into Fort Meadow Reservoir.

2. Incorporate facilities for chemical addition and flocculation into the design of future systems to further improve the stormwater retention basin's effluent characteristics. (It is recognized that this is a costly alternative.)

3. Provide stormwater diversion where such a practice would be cost effective and results in a measurable decrease in nutrient or pollutant loadings.

4. Reduce pollutant burdens at the source (i.e. streets).

The most prevalent problem associated with stormwater runoff in the Fort Meadow Reservoir is not the volume of water transported to Fort Meadow Reservoir, but rather the quality of that water. Contaminants deposited on the urban landscape and subsequently conveyed into the lake can be a potential source of deterioration of in-lake water quality. Stormwater sedimentation basins with or without chemical additives and/or diversion are mechanisms by which this potential source of contamination can be regulated.

Rather than attempt to treat urban runoff at the point of discharge to the lake, it may be more advantageous to attempt to mitigate the stormwater's impact on Fort Meadow Reservoir by removing potential contaminants (i.e. debris, street litter, particulates, auto emissions, etc.) at their source prior to their introduction into the lake. This could be accomplished if an effective street sweeping program were to be implemented in the Fort Meadow Reservoir drainage area. Presently, street sweeping is performed in the drainage basin only on a few times a year basis frequency, typical of the average Massachusetts community.

Street sweeping traditionally done for aesthetic reasons has been shown to reduce impact of stormwater pollution. Much of the material picked up by the sweeper would otherwise end up in the stormwater discharges. Two EPA sponsored studies* have examined the effectiveness of street sweeping with respect to stormwater pollution. It has been found that a great portion of the overall pollutional potential is associated with the fine solids fraction of the street surface contaminants. Data presented in the reports also indicated that current broom-type street sweepers were not excessively efficient in removing the smaller particles. However, the overall efficiency of the street sweeping can be greatly increased with a well-planned sweeping schedule and the use of vacuum-type sweepers which have been shown to achieve removals of up to 95% of the total material on the street.

2. Zoning and Land Use Planning

Historically, the objective of municipal land-use planning and zoning activities can generally be characterized as providing a regulatory structure to allow for orderly growth in anticipation of future needs, responsive to identified regional goals and existing land use, and public safety and welfare requirements. The Towns of Marlborough and Hudson have an established municipal infrastructure to support these activities and only minor modifications to the existing program would be required to modify

*"Water Pollution Aspects of Street Surface Contaminants", Office of Research and Monitoring Report EPA-R2-081 by J.D. Sartor & G.B. Boyd, November, 1972.

"Toxic Materials Analysis of Street Surface Contaminants", Office of Research and Development, by R.E. Pitt and G. Amy, EPA Report No. R2-73-283, August, 1973.

the existing functions to aid in an overall lake restoration program. Modifications to the overall program include:

Requiring future development activities to incorporate adequate stormwater management systems (i.e. modification of sub-division regulations).

Incorporation of adequate sedimentation and erosion control measures into the zoning by-laws, a technique now becoming increasingly popular.

Reallocation, perhaps by re-zoning, of potentially high density development activities to other areas of the Towns other than the Fort Meadow Reservoir drainage basin.

3. Wastewater Management Approaches

The greatest percentage of the Fort Meadow watershed is sewered; however, small enclaves of homes without sewers do exist, including some which are very close to Fort Meadow Reservoir along Red Spring Road, serving about 25 homes. These on-site wastewater disposal systems in the Fort Meadow Reservoir watershed, even though limited, may be malfunctioning and causing potential water quality problems due to one or more of the following causes:

Improper construction methods.

Inadequate design.

Poor subsurface conditions (i.e. glacial till soils with hardpan layers).

Insufficient or non-existent maintenance programs.

It follows that a relatively small but perhaps significant volume of inadequately renovated domestic sewage may be reaching Fort Meadow Reservoir. Groundwater is a component of water flow to Fort Meadow Reservoir and it can be assumed that septic tank leachate is being introduced into the lake in some areas by direct or indirect discharge to the lake in shoreline areas. As noted above, the major area of concern is the Red Spring Road area in Marlborough.

Because malfunctioning on-site disposal systems are a potential problem in the Fort Meadow Reservoir watershed, the implementation of an efficient and cost effective wastewater management plan for the basin is of importance.

b. In-lake Restoration Techniques

1. Aeration and Artificial Circulation

In stratified eutrophic lakes such as Fort Meadow Reservoir, the amount of organic matter that enters the hypolimnion is very large (from dead algae, weeds, animal feces, etc.). Bacterial decomposition consumes the dissolved oxygen shortly after thermal stratification in the spring, and oxygen is not restored to these waters until after lake circulation in the fall. There are a number of undesirable consequences of low or zero oxygen in the hypolimnion. Plant nutrients are released from bottom sediments, and compounds such as methane, iron, manganese, and hydrogen sulfide accumulate. The nutrients may be mixed into the upper, lighted epilimnion at turnover and stimulate algal blooms. The hypolimnion becomes unfit for survival of cold water fishes such as trout and benthic invertebrates. Only a few organisms can tolerate anoxic conditions for prolonged periods, and fish generally do not thrive in habitats where dissolved oxygen is less than 5 mg/l.

Hypolimnetic aeration introduces oxygen to the hypolimnion only, while artificial circulation mixes the entire water column. These techniques free the water of taste and odor, improve the fishery and/or prevent winter fish kills, and attempt to control algae by either controlling nutrient release from bottom sediments by introduction of oxygen, or by circulating cells to depths where low light will limit growth. In hypolimnetic aeration, air or oxygen is injected into the deep water without disrupting thermal stratification, whereas in artificial circulation air is introduced with sufficient force to overcome the density differences between the two layers so that the entire water column circulates.

Since D.O. levels in Fort Meadow Reservoir are reasonably high, even in fairly deep waters, and since the bulk of the nutrient problem is associated with macrophytes rather than with algae, aeration is not considered a cost effective method for Fort Meadow Reservoir restoration. To these concerns must be added interference with recreation and power costs.

2. <u>Phosphorus Precipitation or Inactivation</u>

Nutrient inactivation/precipitation is a lake improvement technique which has been used exclusively to control or lower the concentration of phosphorus in the water column and thereby control the amount of planktonic algae. Inactivation is an attempt at long-term control by stopping the release of phosphorus from lake sediments, while precipitation is the removal of phosphorus from the water column. Inactivation is almost always the recommended procedure. The element most often used to attempt inactivation or precipitation is aluminum.

Adding liquid aluminum sulfate and/or sodium aluminate has been the most frequently used method of precipitating or inactivating phosphorus. These salts work in three ways: by forming aluminum phosphate, by entrapping phosphorus-containing particles in the water column, and by adsorbing phosphorus to the surface of aluminum hydroxide (the main chemical product of the precipitation reaction). The aluminum hydroxide is formed as a floc, or visible particles, in the water. The floc settles through the water column (removing suspended material on the way), and covers the sediment with a blanket of aluminum hydroxide. Water so treated becomes almost instantly clear, and if sufficient aluminum hydroxide has been deposited on the sediments, it has a sealing effect. Phosphorus recycling from the sediments is greatly reduced, phosphorus concentration in the water remains low, and the water continues to be clear. The floc eventually (several months) consolidates with the sediments and is no longer visible.

The amount of aluminum added to the water is the factor which separates phosphorus precipitation from phosphorus inactivation. In the former procedure, just enough aluminum is added to surface water to remove phosphorus from the water column. The exact amount is determined in jar tests. In such cases, dose is small, little if any control of release from lake sediments is achieved, there are few risks of side-effects, and long-term control of algae usually does not occur. Precipitation or phosphorus removal is recommended only for situations in which the sediments are not a significant source of phosphorus. Phosphorus inactivation is recommended for most other situations, since phosphorus release from eutrophic lake sediments usually is a major source of this essential element for growth of algae and may delay lake recovery for many years after external sources have been controlled or diverted.

Nutrient inactivation or precipitation can only be effective in lakes from which significant inputs of nutrients have been eliminated. The techniques are presently used only for algal control, not for control of rooted aquatic plants, therefore potential use at Fort Meadow Reservoir seems limited. Both ponds and lakes have benefited from it, particularly those which flush slowly and stratify. Again, it seems Fort Meadow Reservoir is not an ideal candidate since flushing probably occurs rapidly and the lake is only weakly stratified in the East Basin. Phosphorus release from eutrophic lake sediments usually is a major source of this essential element for growth of algae and may delay lake recovery for many years after external sources have been controlled or diverted. There has been little published experience with the technique in thermally unstratified, highly-mixed lakes such as Fort Meadow Reservoir, therefore, this potential method is rejected.

3. Lake Level Drawdown

Lake level drawdown is a multipurpose lake improvement technique. It has been used to attempt control of nuisance rooted plants, to manage fish, to consolidate flocculent sediments by dewatering, to provide access to dams, docks, and shoreline stabilizing structures for needed repairs, to permit dredging using conventional earthmoving equipment, and to facilitate application of sediment covers. The procedure is often an inexpensive one which can be effective in aquatic plant control where susceptible species are present and where rigorous conditions of dry cold or heat can be achieved for 1 to 2 months. There appears to be significant reason for viewing the method further for Fort Meadow Reservoir.

In some case studies in Wisconsin significant winterkill of macrophytes was accomplished by this method, however, this was often succeeded by algal blooms in the next summer. In Louisiana, drawdown was used to control weeds in order to manage fish. Susceptible plant species were controlled but resistant ones increased. Table II-2 shows a summary of experiences reported by the U.S. EPA in their review of drawdown projects. Note that Potamogeton, Utricularia, and Elodea, all species reported in significant numbers in Fort

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TABLE II-2

RESPONSES OF SOME COMMON NUISANCE
AQUATIC PLANTS TO LAKE LEVEL DRAWDOWN *

A. Increased Abundance After Drawdown

1. Alternanthera philoxeroides (alligatorweed)
2. Najas flexilis (naiad)
3. Potamogeton spp. (most species of pond weed increase or do not change

B. Decreased in Abundance After Drawdown

1. Chara vulgaris (muskgrass)
2. Eichhornia crassipes (water hyacinth)
3. Nuphar spp. (water lily)

C. No Change or Clear Response After Drawdown

1. Cambomba caroliniana (fanwort)
2. Elodea canadensis (elodea)
3. Myriophyllm spp. (milfoil)
4. Utricularia vulgaris (bladderwort)

*Source: EPA Report - 440/5-81-003, December 1980 (modified)

Meadow Reservoir, either increased in abundance following drawdown or else there was not net change or clear response in the growth. When the citizen unpopularity of lake drawdown is added to the above analysis it seems clear the lake drawdown should be eliminated.

4. Weed Harvesting

Aquatic plant harvesting is a procedure to cut and remove (usually) vegetation, giving the lake user immediate relief from conditions impairing swimming, boating, and water-skiing. In few instances could harvesting, by itself, be called a lake restoration technique, since it does not affect external sediment and nutrient income or alter conditions for re-growth, such as shallowness and nutrient-rich lake sediments. As with any other in-lake technique, diversion of sediment and nutrients is essential for long-term lake improvement.

A commonly-used method for controlling excessive aquatic plants is herbicide treatment. Harvesting is at least as effective, is no more expensive, and has several distinct advantages over the introduction of toxic chemicals. The procedure is site and even species specific, and the time and place of harvesting are decided by lake users. The nuisance is immediately removed, and with it a certain quantity of plant nutrients. No poisons are introduced and no toxic residues remain. The lake can remain open during harvesting. The plants do not remain in the lake to decompose, remove oxygen, and release nutrients which may stimulate algal growth. Finally, the harvested weeds may be used for compost, mulch, methane production, etc. Moreover, previous herbicide treatments at Fort Meadow Reservoir, as late as 1980, have proved fruitless in the long-term control of macrophytes, and the practice should probably be abandoned.

There are two general types of weed harvesting systems, those which cut plants, and those which cut and then remove the cut material. Low cost systems simply cut the vegetation; removal occurs after wind and currents move the floating vegetation to shore or to a barrier at the lake's outlet. This type of system is not recommended for lakes in which current is unpredictable (such as natural lakes and many impoundments) since the cut vegetation will ultimately sink, decompose, release nutrients, and consume oxygen. The other system cuts plants to a depth of up to 2.4 meters (8 feet), and a conveyor removes the cuttings to a holding area on the harvester. Cut plants are then transported to shore by the harvester, or to a second vessel which takes them to shore while the harvester continues to cut. This system has a high initial cost but removes the vegetation from the lake at a rate of 1 to 3 hectares per day (4 to 6 acres).

Disposal of cut vegetation is often mentioned as a problem with harvesting. Apparently such problems rarely materialize, since many lakeshore residents have found the material to be valuable as mulch or compost. The dry weight of harvested plants is often 10% or less of the initial wet weight.

Harvesting can contribute to long-term lake restoration if the amount of nutrients removed in the cut vegetation exceeds the lake's net nutrient income. Few eutrophic lakes can be restored by harvesting, although significant amounts of nutrients may be removed.

Re-growth after harvesting is usually delayed, and cutting and harvesting in one year tend to inhibit re-growth in subsequent years. Deeper cuts (nearer sediments) are more effective in controlling re-growth, and multiple harvests in one season are better than a single early-season harvest. Thus, while harvesting is not often a long-term restoration method, it is clearly an effective lake improvement procedure which gives the user immediate access to the water without the problems associated with toxic chemicals. In New England, two harvests per year, generally in early June and late July or early August are usually optimal for effective macrophyte control.

Although they have not been extensively documented, there may be some adverse effects associated with harvesting. Harvesting constitutes habitat removal, and with it will come a reduction in species of the shallow area of the lake, particularly of animals such as snails, insects, and worms. The adverse impact on fish abundance appears to be slight, and only small fish are removed by the harvester (12 to 190 millimeters (0.5 to 7 inches) in length). Fish growth rates may increase, and fish may increasingly turn to algal grazers (zooplankton) instead of snails and insects. Algal blooms often occur after harvesting, and they may be caused by elimination of competition from the rooted plans, by the removal of the algal grazers by fish or by increased light intensities in the photic zone. Another adverse impact may occur if vegetation at incoming streams is removed, since this vegetation probably removes nutrients and traps silt.

The cost of harvesting is greatly affected by the high initial cost of the equipment, but actually seems to compare favorably with herbicides. Costs range from $200.-$300. per acre per season on the basis of two harvests for contracted weed harvesting, including labor (ofen well over half the cost), equipment, depreciation, and disposal. Costs can be be reduced by designing an efficient cutting-transport plan and by municipal purchasing of equipment if the size of the harvesting project is large enough, and other community projects can benefit from the harvester. Initial capital costs for a harvester-transporter system are in the order of $120,000.00.

In summary, harvesting is effective in removing vegetation from lakes at the time and place desired by lake users, without the adverse impacts of herbicides. Costs are about equitable with herbicide treatment costs, and with the possible exception of algal blooms, few adverse environmental impacts have been observed. Re-growth of plants is slowed by multiple cuts and the amount of plants in subsequent years is usually less. Harvesting is not a long-term lake restoration procedure unless the amount of nutrients removed with the vegetation exceeds the net nutrient income to the lake. It will provide immediate relief from nuisance plant growth and improve recreational uses of the lake.

It should be noted that the Federal Clean Lakes Program considers harvesting to be a pallative approach to lake restoration in most cases, and therefore, rarely eligible for financial assistance under Section 314 of P.L. 92-500. It is concluded, however, that weed harvesting in conjunction with limited dredging and watershed management, may offer sizable short-term benefits, and some moderate long-term benefits.

5. Sediment Removable by Dredging

The organic bottom sediments in Fort Meadow Reservoir could be physically removed by dredging the pond. Because Fort Meadow Reservoir is an artificial impoundment which can be lowered significantly, dredging can be accomplished by either of two methods - conventional earth moving equipment or a hydraulic dredge. A final comparison of the cost effectiveness of each of these methods will depend on an engineering evaluation of the relative strength and water content of the organic bottom materials once the pond is drained.

Bottom sediment probing in Fort Meadow Reservoir has shown the benthic materials to consist primarily of silt and muck inconsistently ranging from approximately 0.7 to 1.3 meters in thickness. These relatively soft bottom materials are underlain by granular materials of increased density. At this time, however, additional bottom sediment coring remains to be accomplished before final design plans can be prepared for benthic material removal. An important component of the dredging program design is the dredged material in a confined containment area, if hydraulic dredging is utilized to remove the bottom mucks. Figure I-V shows the results of a column test which approximates expected field conditions. The data show rapid settlement of the solids, typical of mucks with high silt and relatively low organic content.

It is estimated that the removal of an average depth of approximately 1 meter of bottom material over 100 acres of Fort Meadow Reservoir would result in the removal of the bulk of the nutrient rich organic bottom sediments and at the same time would result in the removal of the existing macrophyte root systems throughout the shoreline photic zone. The total material removed in this manner would be approximately 370,000 cubic meters.

If a hydraulic dredge is utilized, the bottom sediments would be removed from Fort Meadow Reservoir by pumping a slurry of sediment and water to a containment area, decanting the supernatent, and perhaps treating it prior to discharge. A site of roughly 30 acres would be needed and at present, the only potential containment area sites which may be utilized providing proper site preparation is accomplished, appears to be the nearby landfill, and that site is probably too small.

The estimated total cost for dredging is approximately \$4.00 per cubic meter based upon recent experience with similar projects. Thus, the total cost of dredging Fort Meadow Reservoir is in the neighborhood of 1.5 million dollars. This cost includes the construction and operation of the containment area.

If conventional equipment were to be used, the lake would be drawndown and the bottom material would be removed and stockpiled, probably using high floation bull dozers. This material would then be loaded onto trucks using front end loaders and brought to a suitable site for drying and stockpiling (i.e. landfill). The dredged material could ultimately be used for various landscaping projects.

The cost for removal of the bottom material by conventional means and a re-grading of the lake bottom to the proposed design contours has been estimated based upon informal discussions with four major contractors. These costs varied from approximately \$3.00 per cubic meter to approximately \$6.00 per cubic meter, averaging \$4.50 per cubic meter. A total cost for dredging by conventional equipment is in the order of magnitude of 1.5-2 million dollars, if an average dredge depth of 1 meter is taken over 100 acres of lake basin. Obviously, by selectively chosing areas of dredging, the costs could be cut back significantly, but the numbers still remain high.

FORT MEADOW RESERVOIR

LAKE BOTTOM MATERIAL COLUMN TEST - SETTLEMENT VERSUS TIME

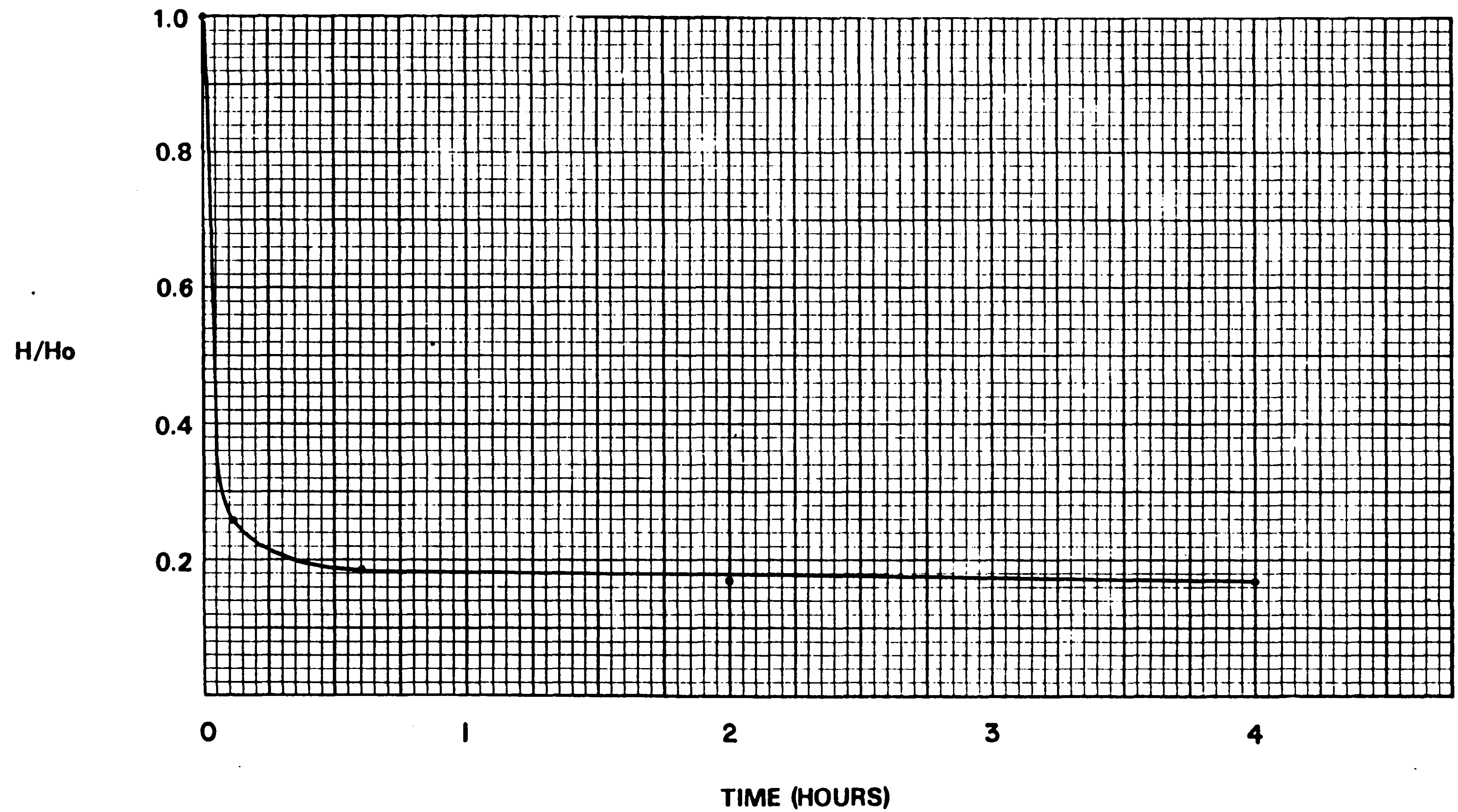

FIGURE I-V

Because of the necessary rehandling, material removal by conventional techniques may, in fact, be somewhat more expensive than removal by hydraulic dredge. However, the costs of dredging are too rough and too close at this stage to definitely say that one method is better than the other.

The principal disadvantages of dredging include possible increases in turbidity, the possible release of nutrients during the dredging operation, and various difficulties associated with the disposal of the dredged materials. In the case of Fort Meadow Reservoir, treatment at the landfill could be combined with ultimate disposal of Fort Meadow Reservoir sediments as a capping material, to reduce leachate production, reducing dredging and disposal unit costs perhaps by 50%.

As noted above, dredging need not necessarily be complete at Fort Meadow Reservoir to be effective. A lesser program involving just the Town beaches or the Town beaches and the East Basin could be a Phase I project, while Phase II could involve the West and Inflow Basins and upstream controls noted under Watershed Management. At this point it seems best to recommend a plan of limited dredging to gain access with a long-term annual dredging and weed harvesting program to gradually restore the Fort Meadow Reservoir. Initial dredging costs along a 1,000 foot shoreline, dredged lakeward 100 to 150 feet to a depth of 5 feet, would bring costs down to the $100,000.00 to $200,000.00 range for initial capital expenditures. This could be followed by annual weed harvesting over perhaps 40-50 acres of the lake for a cost of perhaps $12,000.00-$15,000.00 per annum.

6. Other Techniques (Less Feasible)

a. Dilution/Flushing

One technique for reducing the nutrient loadings within a lake involves the dilution or flushing of the existing pond water, replacing it with water with lower nutrient concentrations. This technique is most applicable when the lake in question has a relatively long hydraulic retention time and there is a readily available source of high quality water, as well as provisions to discharge the lower quality water without causing downstream impacts. Fort Meadow Reservoir has a very short hydraulic retention time and adequate quantities of sufficiently nutrient free replacement water are not available at reasonable costs. Moreover, Fort Meadow Brook has been classified by

Massachusetts DWPC as an anti-degradation stream segment, and so cannot be the recipient of flushed waters.

b. Bottom Sediment Sealing

Sand, fly ash, and various chemicals have been used to seal the pond bottom and prevent the mass transfer of nutrients from the bottom sediments into the water column.

Sand, gravel, fly ash, and various plastic or rubber liners have been utilized on relatively small ponds to act as a physical seal. The principal problems with this method are relatively high costs, the sinking of the sand and gravel below soft benthic sediments, and potential gas formation and/or rupturing of the liner.

Chemical sealing has been carried out with clays and fly ash and has the additional advantage of tieing up soluble phosphates in the water column and holding them on the bottom as relatively insoluble species. Potential problems with this method include heavy metal and other impurities often associated with fly ashes and the difficulty of providing a satisfactory seal with clays especially when the bottom is comprised of relatively light specific gravity organic materials. This problem would be compounded in a lake with a short hydraulic retention time, such as Fort Meadow Reservoir.

These methods are not considered appropriate for use in Fort Meadow Reservoir primarily because of the lake's relatively short hydraulic retention time, its organic bottom material, and the relatively high cost of sealing as compared to other more appropriate methods.

III. CONCLUSIONS/RECOMMENDATIONS

As a result of this limited investigation, it has become apparent that the major causes of nuisance aquatic plant problems in Fort Meadow Reservoir, in probable order of significance, are:

1. Solids and associated nutrients delivered with stormwater flows.

2. Septic system discharges, especially from the Red Spring Road area in Marlborough.

3. Possible residual leachate seepage from the Marlborough landfill, which is avoiding the leachate diversion system.

4. Other miscellaneous sources, such as the Pleasant Street point source discharge and atmospheric fallout.

It is recommended that the C.O.E. consider the possibility of completing the equivalent of a Phase I Diagnostic/Feasibility Study, consistent with Appendix A requirements of the Federal Register of February 5, 1980. Such an investigation would yield additional pertinent diagnostic information and would enlarge the feasibility options for Fort Meadow Reservoir, reducing the number of alternative scenarios and focusing upon a phased, cost effective, environmentally acceptable plan of action. Part of this plan of action should perhaps be an evaluation of the effectiveness of the present leachate diversion system and recommendations to improve its reliability, if necessary. The above noted level of investigation would also make Fort Meadow Reservoir eligible for Phase II (implementation phase) EPA funding under the Federal Clean Lakes Program (Sec. 314 of P.L. 92-500), and for State funds under the newly instituted 628 funding approved by the Legislature.

At present, from limited observations, it appears prudent to recommend that the Towns of Marlborough and Hudson consider a plan of action which includes out-of-lake watershed management schemes at whatever level is affordable, limited in-lake dredging, especially in beach areas, and an annual weed harvesting program to prevent re-population by nuisance vegetation.